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THE LAZY-H VERTICAL

A versatile antenna for DX work

Verticals can be effective DX antennas on 80 and 160 meters. There are, however, some practical problems involved in building such antennas. A quarter-wavelength vertical, for example, will be ≈ 68 feet high at 3.510 MHz and 131 feet at 1.840 MHz. If you use buried radials, you'll need an extensive ground system of radials >0.2 wavelength for efficient operation. Both the height and the ground system can make such a project formidable and put this kind of antenna out of reach for many hams.

What's needed are designs whose performance approaches these ideals, but don't require the height, ground area, and/or complexity of ground system. Wire antennas that may be hung between a tower and a tree or two trees would be quite useful. It's also important that the designs be very flexible in their dimensions, mechanical details, materials, etc., because each situation is different and the antenna must be crafted to fit the available site and resources. This may sound like a tall order, but you can come surprisingly close to filling it.

Al Christman, KB8I,[1,2] has shown that a relatively simple elevated radial system, *isolated* from ground, can provide performance comparable to large buried radial systems. Also, it has long been known that the height of a vertical may be significantly reduced while maintaining good efficiency, by using top loading.[3] Shortening the top-loaded antenna reduces the bandwidth, even if it doesn't significantly reduce the efficiency. This isn't necessarily a problem for DX work on the low bands, because DX operation is highly localized in the "DX windows." With 80 meters, there are two windows—3.510 (CW) and 3.790 (SSB) MHz. Even using a relatively short antenna, it's possible to get 50 to 100 kHz of 2:1 SWR bandwidth. Because the two DX windows are almost 300 kHz apart, some trickery is needed to accommodate both windows with a single antenna. As I'll show you later, both of these

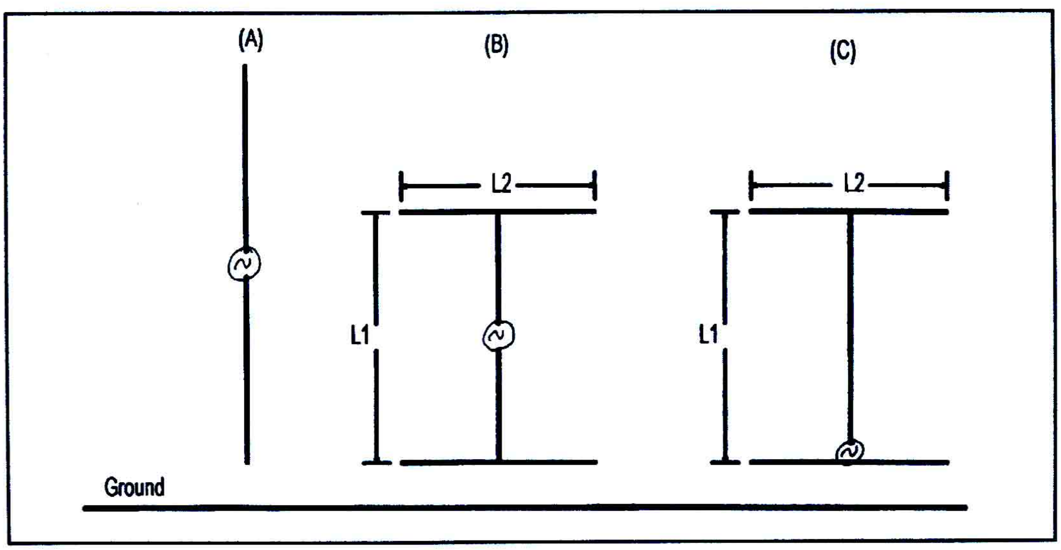

Figure 1. (A) A half-wave vertical dipole. The antenna can be shortened by adding perpendicular wires at the ends (B) and (C).

Table 1. Antenna Comparison at 3.510 MHz

ant	L1	L2	Z_{middle} Ω	Z_{end} Ω	peak gain, dB	peak angle °	wire loss -dB	2:1 SWR Bw kHz
λ/2	137'	0	91	>5000	+.30	16	.08	270
lazy-H	120'	4.4'	96	1096	+.28	17	.02	280
"	100'	10.4'	94	384	+.12	19	.07	280
"	80'	17.4'	81.3	180	-.06	20	.08	260
"	69.8'	21.6'	71.2	127	-.07	21	.09	240
"	60'	26.3'	59.7	90.9	-.15	22	.10	200
"	40'	38.3'	33.7	40.8	-.38	24	.16	140
"	30'	45.6'	21.5	23.8	-.59	25	.23	100
λ/4 2 radials	69.8'	———	———	38.8	.11/-.39	22	.15	200
λ/4, 4 radials	69.8'	———	———	35.7	+.21	22	.13	175

windows may be accommodated in a single antenna by simply switching in a capacitor in series with the input for 3.790-kHz operation.

Top-loaded verticals with elevated radials can take many forms. I'll explore a particularly useful form that looks like an H turned on its side. I call it the lazy-H vertical, for its resemblance to the classic lazy-H antenna. This antenna is functionally the same as the Discpole that appeared in the summer 1996, *Communications Quarterly*.[4] The Discpole antenna was designed for 2 meters and uses solid disks at each end. At low HF frequencies, it's generally impractical to use solid disks. Instead of a disk, two or more wire radials are used at each end. The 160-meter example given later does use a solid rectangular "disk" on the bottom end. The disk is actually the metal roof of my house, which was pressed into service. In general, at low frequencies, wire radials will be used. Keep in mind that the Discpole antenna may also be used with conical, as well as flat disks. As I'll show later in the context of sloping lower radials, the angle of the conical disk allows another degree of freedom in adjusting the driving point impedance. This is more useful in short antennas than long, however. The Discpole article has many useful things to say that are relevant to the lazy-H, and I recommend reading it in conjunction with this article. Moxon, G6ZN,[5,6] has also presented antennas that are closely related to the lazy-H. In fact, a lazy-H vertical appears on page 121 of his book. His articles make interesting reading. There's really nothing new in the idea behind the lazy-H antenna. A recent article in *QST* discussed the first trans-Atlantic QSOs made by hams in 1921. The antenna they used was essentially identical to the lazy-H, except that rather than using two elevated radials at the bottom, they used a fan of 30 elevated verticals.

The paragraphs below include the results of extensive modeling using NEC2 software and full-scale testing of three antennas—two for 80 meters and one for 160. For all the modeling, average ground ($\varepsilon = 13$, $\sigma = 0.005$ S/m) was assumed. The lower ends of the antennas are at 10 feet, and the antennas were modeled using #12 copper wire. A check was made on the effect of varying the height above ground from 3 to 15 feet. The effect was quite small and the information for 10 feet is representative. Wire losses are included in the gain comparisons. All of the modeling comparisons are made on 80 meters, but very similar results would be found for 160 meters when scaled appropriately for wavelength.

Most of the following discussion assumes the lazy-H version with two radials at the top and two at the bottom, all in the same plane. More radials, arranged symmetrically, may be used at both top and bottom and may improve performance. In particular, the SWR bandwidth will increase when more radials are used.

The half-wave vertical

A half-wave vertical dipole (**Figure 1A**) is a very effective DX antenna. However, it's too tall (137 feet on 80 meters, 260 feet on 160 meters) to be practical for most of us. You can shorten the antenna by adding perpendicular wires at the ends as shown in **Figures 1B** and **C**. The end wires provide capacitive loading. For a given height (L1), the length of the end wires (L2) may be adjusted to resonate the antenna. By adding the end wires, you can feed the

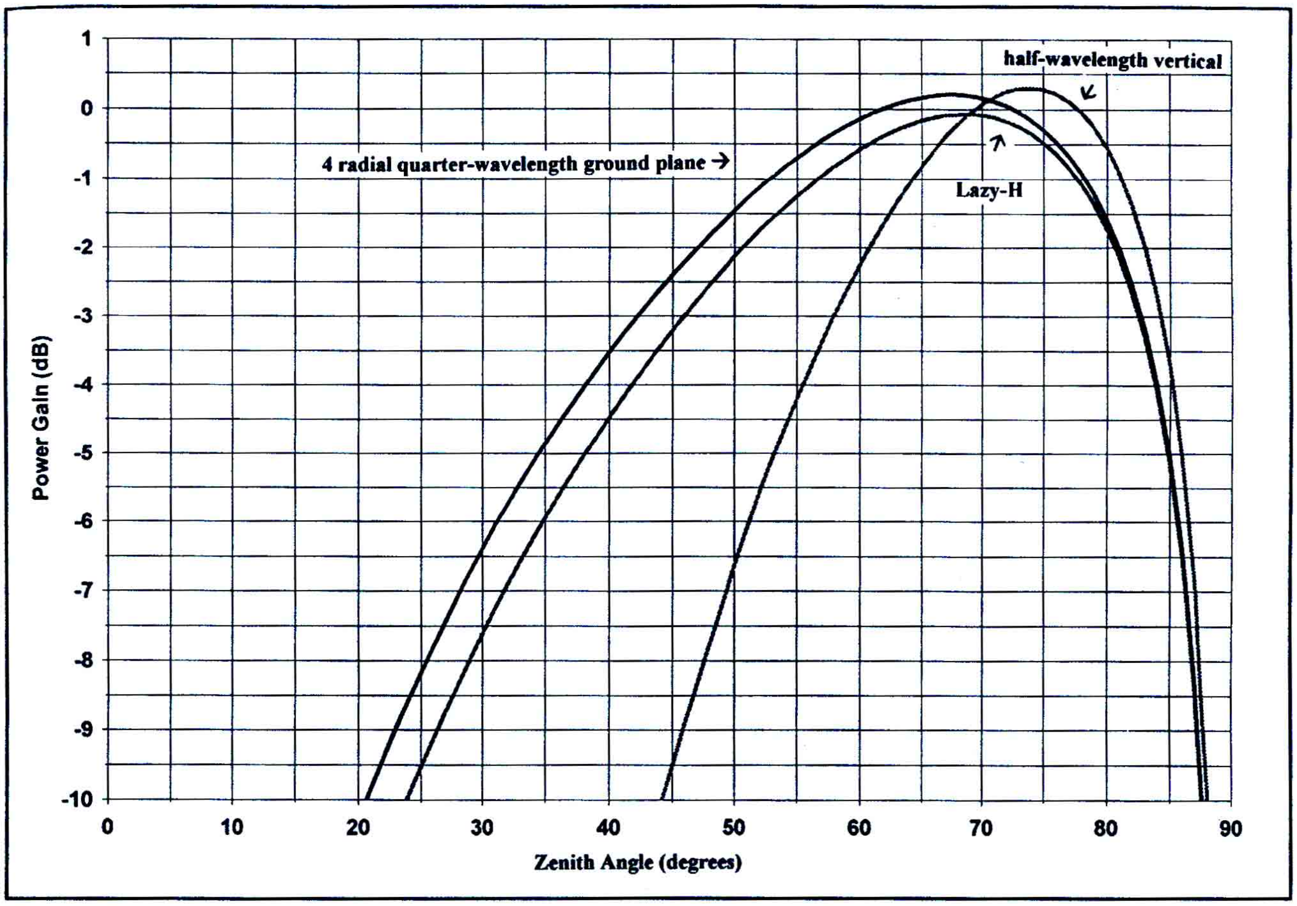

Figure 2. Elevation pattern comparison between 80-meter versions of a half-wave vertical dipole, a quarter-wave antenna with 4 elevated radials, and a lazy-H with L1 equal to a quarter wavelength.

antenna either at the center (B) or, more conveniently, at the lower end (C), which may be near ground level.

How good is this antenna compared to the half-wave vertical dipole or the quarter-wave antenna with a multi-wire elevated ground system? **Figure 2** provides an elevation pattern comparison between 80-meter versions of the half-wave and quarter-wave with 4 elevated radials (a ground plane antenna) and a lazy-H with L1 = $\lambda/4$ (69.8 feet).

The difference between the lazy-H and the quarter-wave ground plane is less than 0.3 dB. You won't notice that on the air. The gain difference between the half wave and the lazy-H is slightly larger, 0.37 dB, but there's an important difference in the peak gain angle. The peak angle is higher in the shorter antennas.

Table 1 provides a more detailed comparison of the lazy-H with values of L1 from 30 to 120 feet, the quarter-wave ground plane with 2 and 4 radials, and the half-wave antenna.

There's some interesting information presented in this table:

1. The peak gain difference between a full-length half wave and L1 reduced to 30 feet is less than 0.9 dB. This difference could be reduced to <0.7 dB if the vertical 30-foot section were made from larger wire or aluminum tubing to reduce the loss.

2. The peak radiation angle is increased from 16 to 25 degrees when L1 is reduced to 30 feet. This is due to the reduced length of the vertical radiator and there's no magic which will change that except to make L1 longer, or to raise the height of the entire antenna. The gain reduction at low angles for L1=30 feet compared with the half wave is shown in **Figure 3**. Even at the lowest angles the short lazy-H is within 2 dB, which is only a fraction of an S unit. The short antenna is still in the game! Because of the symmetrical end loading, the radiation resistance at the current maximum will be higher than other configurations for the same L1. The shortened antenna efficiency can be quite high if care is taken.

3. Compared to the quarter-wave ground plane, the 30-foot lazy-H is very close in peak radiation angle (25 degrees versus 22) and the peak gain is down by less than 0.8 dB, which could be reduced further. Even at 30 feet this antenna is competitive.

4. The gain, bandwidth, and efficiency of the lazy-H are very competitive with the half-wave

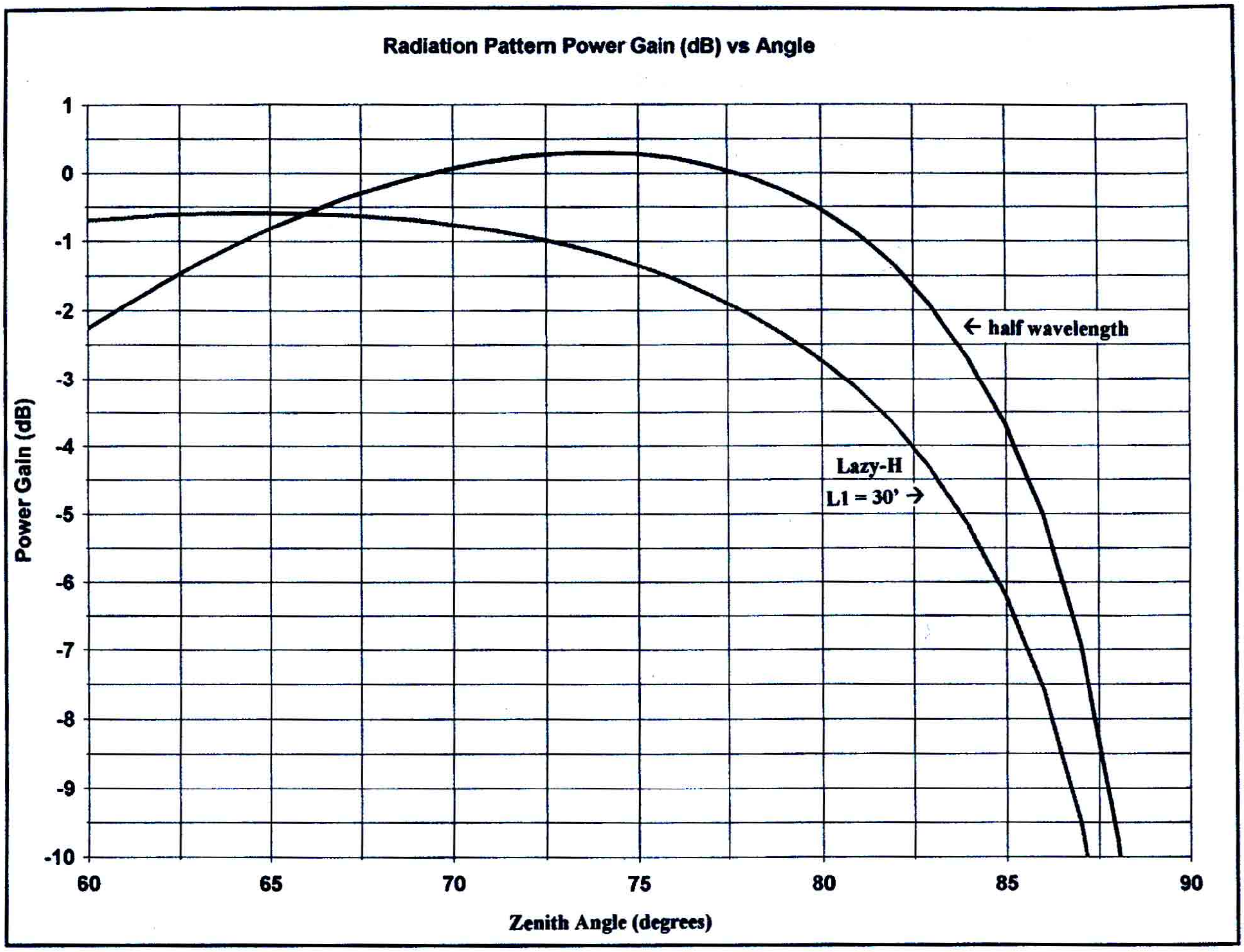

Figure 3. Gain reduction at low angles for L1 = 30 feet, compared with the half wave.

dipole for L1 > 50 feet (≈ 0.18 λ).

5. When compared to the quarter-wave ground plane with 4 radials, the quarter-wave lazy-H has a slightly lower peak gain (-0.28 dB), but also has a lower radiation angle (21 degrees). Performance-wise it's very close. However, the radials on the lazy-H are only 21.6 feet as opposed to 70 feet, and there are only two of them near ground. The lazy-H takes up much less real estate.

6. **Table 1** also lists a two-radial version of the quarter-wave antenna. Two values of peak gain are provided because the azimuth radiation pattern is slightly oval (about 0.5 dB). The maximum gain is broadside to the radials. As the height of the antenna is increased beyond a quarter wave, or if top loading is added to the quarter-wave antenna, the asymmetry in the pattern decreases very quickly.

Asymmetric lazy-H antennas

While the lowest loss is usually obtained when the upper and lower radials are equal and the current maximum is at the center of the vertical section, it's possible to have the lower radials longer than the upper or vice versa. The two-radial, quarter-wave antenna in **Table 1** could be viewed as an example of a lazy-H with zero-length upper radials. The difference in performance is quite small. One interesting feature of the two-radial ground plane is that the lower radials shorten very rapidly when even a small amount of top loading is used. One of the examples given later shows this clearly: where you have 3.5-foot radials at the top, reduce the length of the bottom radials from 70 to 54 feet. Adding top radials also reduces the asymmetry in the azimuth pattern, causing it to become very small in the symmetrical lazy-H.

With only small differences in performance, for a given length L1, the antenna can have a variety of proportions (see **Figure 4**). The length of the vertical section is also a variable. Usually the structure will be adjusted to be resonant inside the band, but even that is unnecessary. There are times when it may be advantageous to make the antenna resonant below the lower band edge to achieve a more convenient input impedance. The accompanying inductive reactance can be tuned out with a very low-loss series capacitor. These variations in shape and/or resonant frequency may be used to accommodate the requirements of a given site, or to manipulate the driving-point impedance or both.

When the antenna is suspended between two supports, the top radials won't be exactly parallel to the ground. They'll need to have some droop toward the center as shown in **Figure 5A**. This doesn't greatly affect the performance. The droop will reduce the length of the vertical section (L1), but this is offset to a degree by the vertical current component in the sloping radials.

The bottom radials may also droop as shown in **Figure 5B**; this can be exploited to vary the input impedance. It's well known that varying the angles for the 4 radials in a ground plane antenna provides a means for adjusting the feedpoint impedance.[7] The same thing happens in the lazy-H antenna.

If the antenna is suspended from a single support, the top radials may droop downward as shown in **Figure 5C**. A small amount of droop (<20 degrees) has very little effect, but a droop of 45 degrees or more will have the same effect as reducing L1. Where L1 is self-supporting (aluminum tubing or a tower for example), it's possible to use rigid radials for a portion of the top and then let the ends hang down as shown in **Figure 5E**. To make these variations work well, it's a very good idea to model them using EZNEC[8] or similar software.[9]

Feeding the antenna

There are many ways to feed this family of antennas, but there's one requirement you must keep in mind: these antennas are isolated from ground. This isolation must be maintained if the antennas are to work as advertised. For example, in the Discpole article, the antenna was fed at the junction of the vertical section and the lower disk. The antenna was isolated with a coaxial choke-balun, like that shown in **Figure 6**, with a shunt inductance of χ1 µH. At 146 MHz, that represents an impedance of 917 ohms, or roughly 20 times the feedpoint impedance. In my work with these antennas, I found that to be good rule of thumb. For the 80-meter asymmetrical antenna with a 50-ohm feedpoint impedance, 20x = 1000 ohms, which corresponds to 45.3 µH. That proved to be the minimum impedance necessary for isolating the feed. In the end, I used 100 µH and obtained good isolation. The balun in **Figure 6** may be scaled up to provide excellent isolation on 80 and 160 meters. For 100 µH and 1500 watts continuous, I use 30 turns of RG-214 wound on an 18-inch section of 8-inch diameter PVC pipe.

A less aggressive, but still perfectly serviceable, choke could be made using RG-8X wound on 4-inch PVC drainpipe. This inexpensive pipe is available from most building supply stores in 10-foot lengths. Some of the small Teflon™ insulated cables would be very good for this purpose.

The ground-plane antenna with four drooping radials is an old-time example of a floating antenna that benefits from isolation. A number of articles have mentioned the need to decouple the feedline and support structure from the antenna. The AEA isopole antenna is a good example. The antenna uses two conical skirts, the first represents the "radials" and the second is for decoupling.

I've used a 1:1 balun wound on toroidal ferrite cores a la Jerry Sevick.[10] These can work well, but you need 2- to 3-inch diameter cores with perhaps two or three cores stacked, to obtain sufficient inductance for low-band use. This is especially true if you're trying to isolate an antenna where Z_{end} is substantially greater than 50 ohms.

It's easy to tell if you don't have sufficient

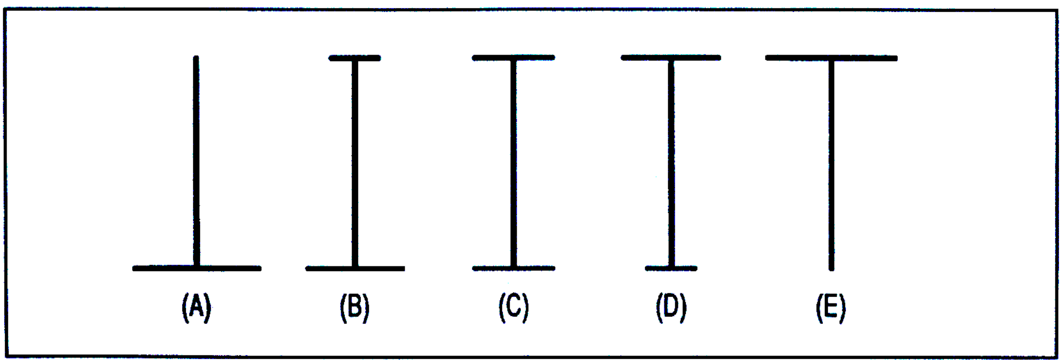

Figure 4. The aysmmetric lazy-H can have a variety of proportions with only a small difference in performance for a given length, L1.

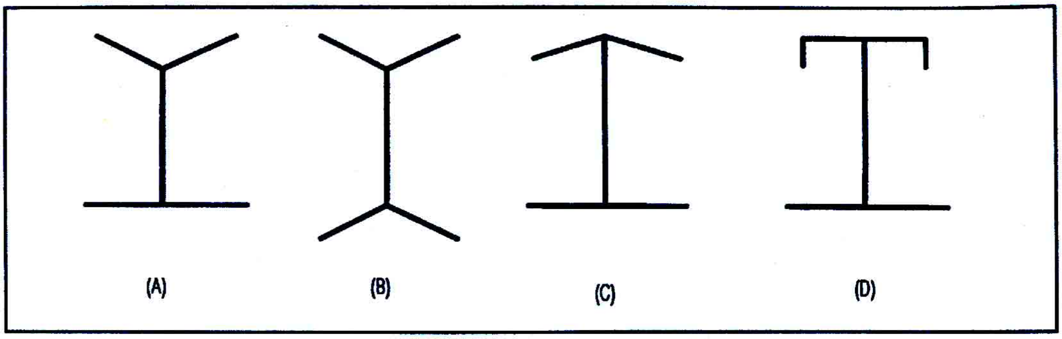

Figure 5. (A)When antenna is suspended between two supports, the top radials will have some droop towards the center. (B)The bottom radials may also droop. (C)If the antenna is suspended from a single support, the top radials may droop down. (D) It is possible to use rigid radials for a portion of the top and let the ends hang down.

isolation. When making measurements with an isolated instrument like the MFJ-249 or the AEA HF analyst, the SWR measurements will change as the instrument is touched. You'll see an even stronger reaction if the transmission line to the shack is touched to the instrument. Another strong indication of insufficient isolation occurs when the resonant frequency is quite different from expected. I noticed this effect in a symmetrical 80-meter lazy-H with a 200-ohm feedpoint impedance when feeding it with a 4:1 balun. The shunt impedance of the balun wasn't nearly high enough, and attaching the coax shifted the resonant frequency from 3.510 MHz down to 3.340 MHz. The resonant frequency was very sensitive to the position of the feedline.

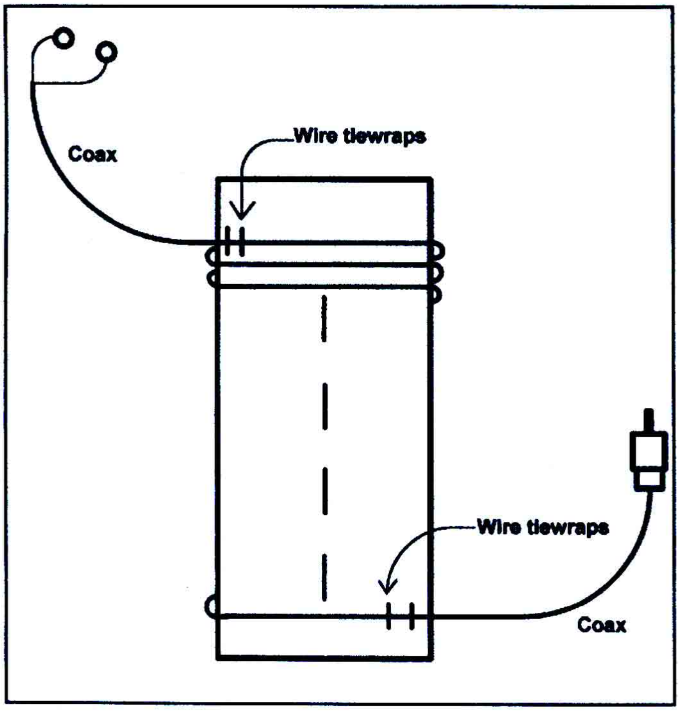

Figure 6. Coaxial choke balun.

These antennas can be fed at any point on the vertical section (L1) by the simple expedient shown in **Figure 7**. The coax shield is connected to the radials at the bottom of the antenna. The coax ends at the desired feedpoint and the rest of the vertical section is formed by a wire connected to the center conductor as shown. Of course, the end of the coax must be carefully sealed to keep moisture out of the cable. The minimum impedance is found at the current maximum. In a symmetrical lazy-H that is at the center of the vertical section. As shown in **Table 1**, the impedance at the center (Z_{middle}) and the bottom end (Z_{end})depend on the length of the center section. As you move away from the current maximum, the impedance rises. For L1 = 50 feet Z_{middle} is very close to 50 ohms. In fact, any length between 45 and 60 feet will give a good match to 50-ohm line. As L1 is shortened further, the feedpoint may be moved from the center towards the end—although for lengths as short as 30 feet, the difference between the center and the end is quite small because there's little difference in the current amplitude. For short antennas, where Z_{end} is low, you can use shunt feed (gamma, delta, omega matches). An example of this for a 160-meter antenna is given later.

The length of L1 that is made up by the coax cable can simply be an extension of the coax in the choke.

For lengths of L1 > 60 feet on 80 meters, there's no point (in a symmetrical lazy-H) on the antenna that's close to 50 ohms and, consequently, other schemes must be used. There are several possibilities:

1. For lengths longer than 65 feet, a point can be found between the center and the end where Z = 112 ohms. A quarter-wave length of 75-ohms coax will transform the 112 ohms to 50 ohms. At 3.510 MHz, using V = 0.66 coax, the length of the coax will be about 46 feet. Only a portion of this length will be needed to form the lower part of L1. The rest can simply be incorporated into the choke-balun.

2. For L1 of 80 feet or more, a 200-ohm point can be found and fed with a 4:1 balun. Be careful, however, most 4:1 commercial baluns don't have sufficient isolation for 80- or 160-meter operation. A coaxial choke will still be needed to provide the isolation on the 50-ohm side of the 4:1 balun. The shunt impedance of the matching balun will provide some isolation, and can reduce the size of the choke.

3. For a given L1, the radiation resistance will increase as longer radials are added at top and bottom. This technique may be used to increase the feedpoint impedance, but will of course introduce a series inductive reactance as the antenna resonance is lowered. This can be tuned out with a series capacitor.

4. The feedpoint impedance can be manipulated by use of asymmetrical radials top and bottom. An example of this is given later.

5. It's possible to adjust the length of the radials to make the feedpoint impedance complex then use a transmission line section to transform this to 50 ohms. A more detailed explanation of this idea will be presented in a later article.

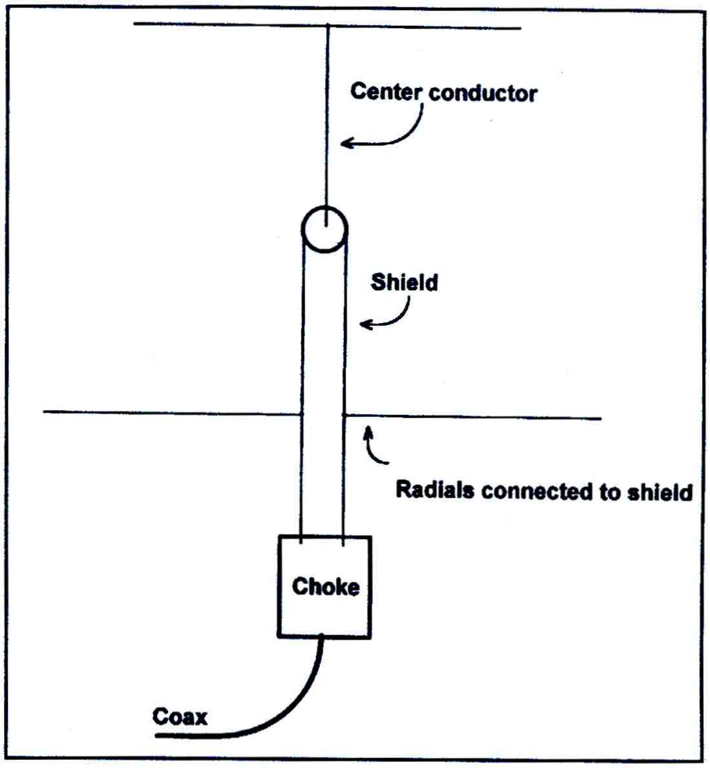

Figure 7. These antennas can be fed at any point on the vertical section (L1) using the method shown here.

A 160-meter lazy-H

Figure 8 shows one of several early versions of my lazy-H. The vertical section is 54 feet high, and there are two 55 foot radials at the top. My house has a metal roof, so I connected all of the panels together with copper strapping (soldered and screwed to the metal) to form large ground plane (≈ 35 x 60 feet). I used this as my lower "disk." Even with such a large area, it was still necessary to use an isolation choke. The gutter system is plastic, so the outer edges of the roof are isolated from ground.

For this short vertical (0.11 wavelength), the highest impedance point is only ≈ 18 ohms. As shown in **Figure 8A**, I used a shunt-feed variation to match the antenna. Textbook pictures of the shunt feed show a wire attached part way up a tower and sloping back to near ground. The inductive reactance introduced by the loop formed by the shunt wire and the tower is tuned out with a series capacitor. When you try this with a wire vertical the "tower" bends, and the bottom of the antenna looks more like a triangle. In fact, I did some modeling to determine the shape and dimensions for the match. I found out that there are any number of proportions which will provide a match. The equilateral triangle offers the best match bandwidth, although deviations aren't greatly different.

The final experimental dimensions for the match are provided in **Figure 8B**. The geometry isn't quite equilateral, but the bandwidth is good. Adjustment is straightforward. I began by fixing the distance along the base of the triangle (the attachment points on the roof), then moved the tap point along the vertical wire with an alligator clip on the shunt wire. I adjusted the length of the shunt wire to keep it approximately equal to the length of wire from the tap point down. The series capacitor is adjusted for minimum SWR at each tap point. It only took a short time to find a good match. When adjusted for minimum SWR at 1.840 MHz, at 1.8 MHz SWR = 1.5 and SWR = 2 at 1.950 MHz. I noted one interesting thing while I was adjusting the match. If I didn't try to get the SWR down to 1.0 at 1.840 MHz, but instead tried to extend the SWR < 2 bandwidth, I could obtain a double humped SWR curve with the maximum SWR < 2 over the entire band. The minimum SWR points were about 1.4, and the hump near mid-band about 1.7. Also, adjustment of the resonant frequency of the antenna (by changing the length of the top radials) could be used to improve the bandwidth.

When the radiation resistance gets this low, wire antennas start to get lossy. To reduce losses, I made the vertical section and a portion of the top radials from some 0.5-inch copper strap I had on hand. I could have done even better if I had made L1 from aluminum pipe, with guys, but the difference wouldn't have been worth the trouble.

I put this antenna up just before the 1996 ARRL 160-meter CW DX Contest. In a few

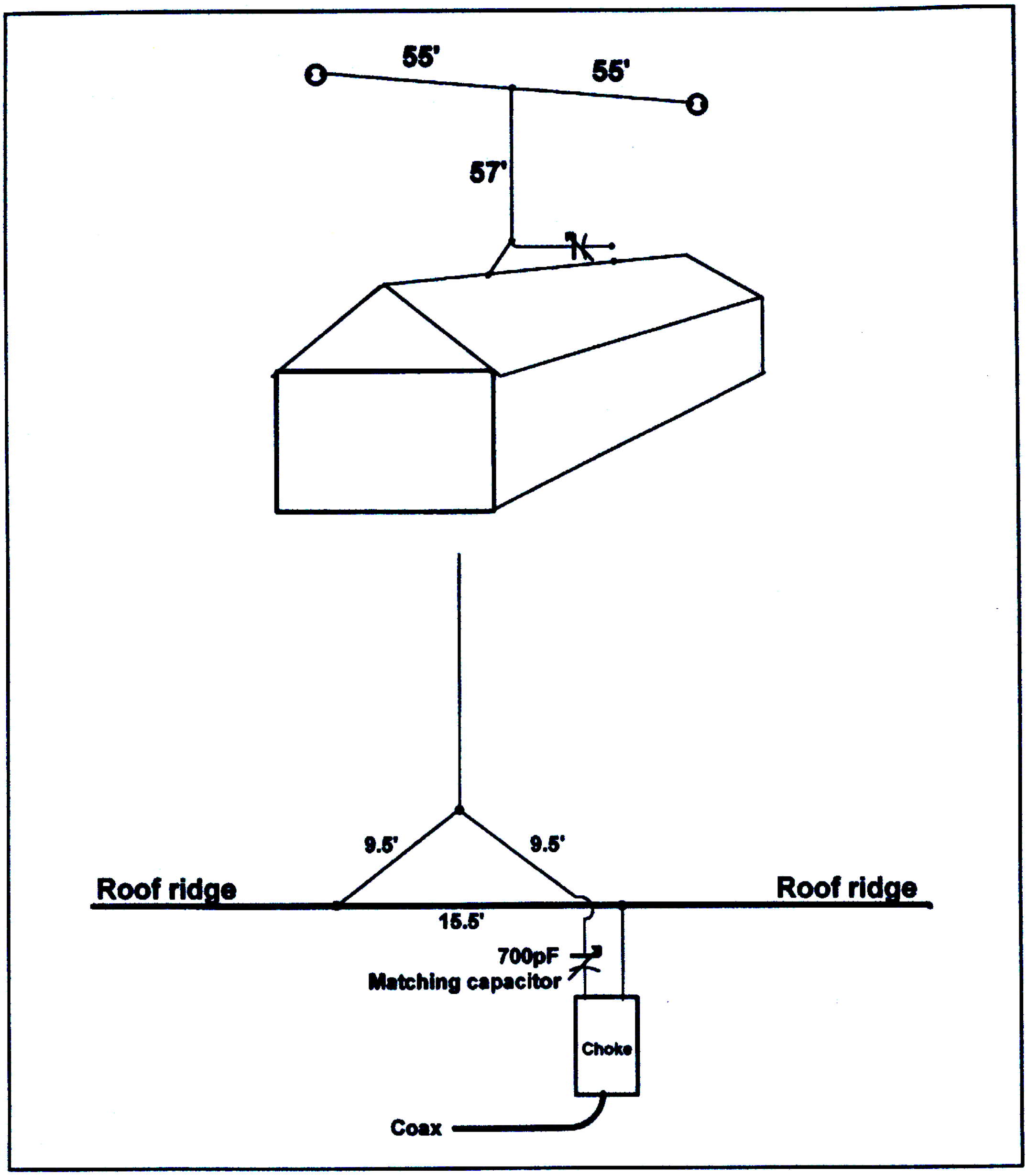

Figure 8. (A) Antenna is matched with a variation of the shunt feed. (B) Final experimental dimensions.

hours of casual operating, I was able to work 45 states—including KL7 and KH6, several VE provinces, XE, and some other DX. (I would have liked to work all 50 states at one sitting, but much of the northeast was QRT due to power losses caused by ice and snow.) I accomplished all this while running only 800 watts. I've been very pleased with this antenna; it's clearly effective. I'm now scheming how to get L1 up to 100 feet, or so!

An 80-meter symmetrical lazy-H

I built a symmetrical lazy-H for 80 meters like the one shown in **Figure 9**. The radials were about 22 feet and the feedpoint impedance, when resonant at 3.510 MHz, was about 130 ohms. This wasn't a very convenient value, but I noticed during modeling that the impedance increased above resonance. By making the radials longer (27 feet), I could move the resonant point down and increase the feedpoint impedance. **Figure 10** shows the feedpoint resistance and reactance from 3.5 to 3.8 MHz, with a 130 pF series capacitor to reresonate the antenna within the band. The resistive component varies from 155 to 250 ohms.

This provides a reasonable match to 200 ohms. However, a single capacitor doesn't provide sufficient 2:1 bandwidth to allow operation at both 3.510 and 3.790 MHz, so I resonated the antenna at 3.550 MHz with a 140 pF capacitor as indicated in the figure. I could have used two capacitors and a relay or switch to change between the CW and SSB DX windows, but I moved on to the next antenna instead.

The antenna worked very well with SWR = 1.2 at 3.550 MHz and a 2:1 SWR band width of 220 kHz.

An 80-meter asymmetrical lazy-H

The final version, which I'm using now, appears in **Figure 11**. The gain of this version is slightly lower than the symmetrical design, but the feedpoint impedance is a convenient 50 ohms when resonant at 3.510 MHz. The SWR = 1.1 at 3.510 MHz, rising to 2 at 3.625 MHz.

To accommodate 3.790 MHz operation, I inserted a 400 pF capacitor in series at the feedpoint, which is shorted out for 3.510 MHz operation as shown in **Figure 12**. Most of my operation is at the CW end of the band, so I chose to use the normally closed (NC) relay contacts. That way, if the relay failed to activate, I would only lose the SSB window.

I also chose to use a separate pair of wires for the relay power, but I could have used the coax itself with an isolation choke; however, I wasn't feeling very clever that day. The relay is one of the old-fashioned types designed to switch

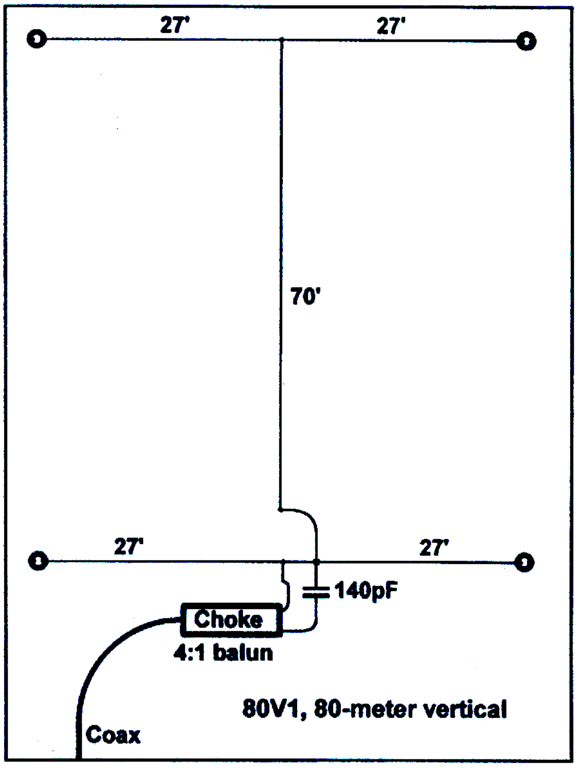

Figure 9. Eighty-meter symmetrical lazy-H.

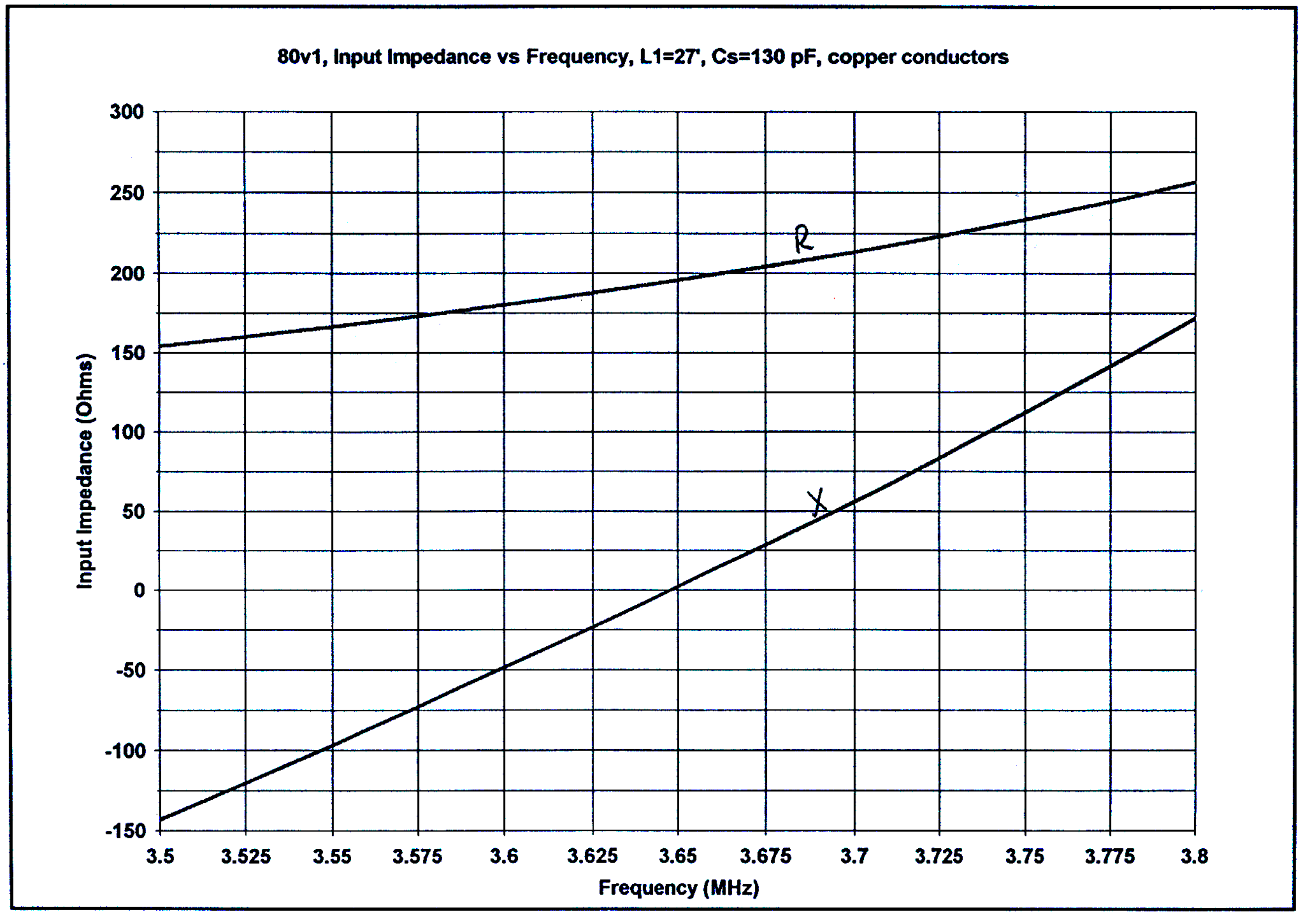

Figure 10. Feedpoint resistance and reactance from 3.5 to 3.8 MHz.

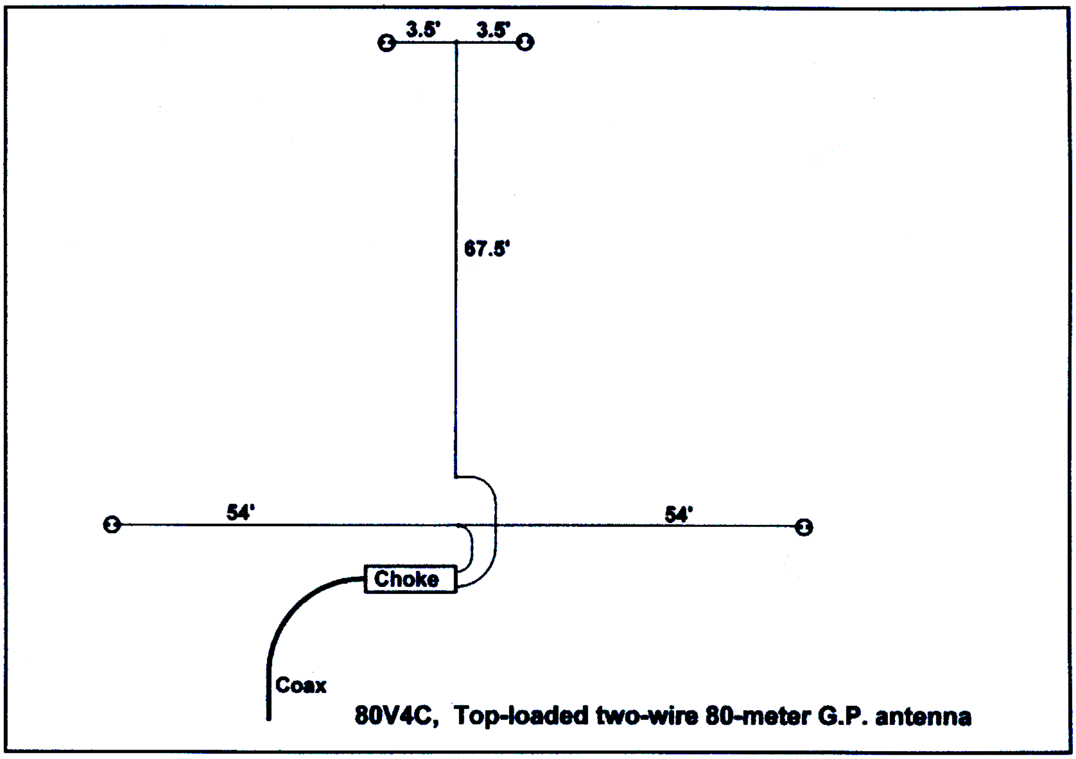

Figure 11. The final version of the 80-meter asymmetrical lazy-H.

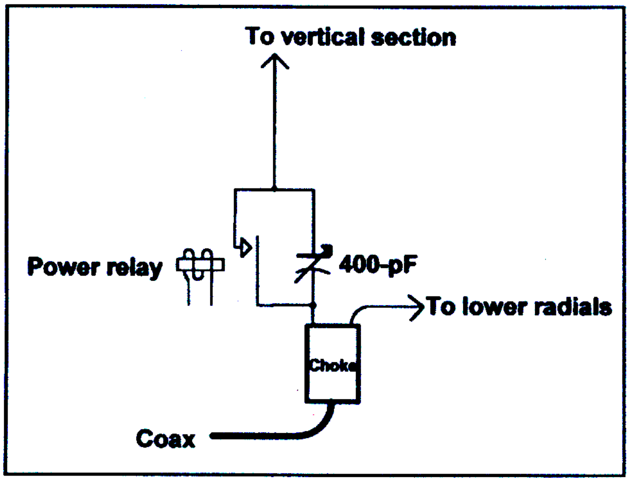

Figure 12. A 400-pF capacitor inserted in series at the feedpoint shorts out the circuit for 3.510-MHz operation, allowing operation on 3.790 MHz.

open-wire transmission lines, and has very little capacitance between the contacts and the coil. It also has very good voltage isolation, but even so, I had to be very careful with lead dress to prevent RF coupling RF back into the relay power lines. If you don't want to monkey with the complexity of a relay, you can use a simple alligator clip and a piece of wire as shown in the figure. If you opt for this method, you'll have to run outside to change frequencies.

When I first fired up this antenna, I was immediately able to work South American stations despite the high noise levels. I'm looking forward to using it under better conditions; I expect it will be very effective.

Conclusion

This family of antennas offers performance comparable to a quarter-wave vertical with an extensive ground system, but is much simpler and less expensive to build. The antennas may be varied greatly in dimensions and materials to accommodate a wide variety of situations and requirements. They are effective DX antennas and worth your consideration. ■

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